

ENVIRONMENTAL INTERACTIONS IN SPACE EXPLORATION:

ENVIRONMENTAL INTERACTIONS WORKING GROUP

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INTRODUCTION

With the advent of the Space Exploration Initiative as mandated by the President of the United States in his twentieth anniversary speech commemorating the first Moon landing, the possibility of designing and using new space systems on scales not heretofore attempted opens before us exciting new challenges in systems design and space science. The environments addressed by the Space Exploration Initiative include the surfaces of the moon and Mars, as well as the varied plasma and field environments which will be encountered by humans and cargo en-route to these destinations from the surface of the Earth, or from low Earth orbit. It is fully expected that systems designers will have to take into account the environmental characteristics for which they are designing. They will need to understand the interaction mechanisms to which their systems will be subject and be able to model them from the earliest conceptual design stages through to design completion.

Planetary and space environments are interactive with man-made systems in a variety of ways, as experience has already shown. Lunar dust physics is dominated by electrostatic forces. The martian surface environment differs from that of the moon in that it consists both of sand and dust, and a dust-laden, low pressure atmosphere in which Paschen electrical breakdown can occur at voltages ranging from a few hundred volts upward. The space environment is dominated by plasmas and fields with a wide range of energies and other physical characteristics. In addition to these natural environments, humans will produce local environments of their own which will modify what is already there and have to be dealt with on their own terms. The characteristics of system/environmental interactions depends on both the characteristics of the local environment, and those of the system. Different system scale sizes lead to different types of interactions and require different mathematical models to enable understanding, evaluation, and prediction.

To the end of understanding environmental interactions for the Exploration Initiative, an Environmental Interactions Working Group has been established as part

of the Engineering Requirements Subgroup. This working group is chaired by Joe Kolecki of NASA Lewis and draws its membership from a broad scope of disciplines. The current paper describes the working group and gives an update on its current activities. The working group charter and operation are reviewed, background information on the environmental interactions and their characteristics as we understand them is offered, and the current status of the group's activities are presented along with anticipations for the future.

ENVIRONMENTAL INTERACTIONS WORKING GROUP

Space system/environmental interactions comprise a set of phenomena which occur when a system is placed into an environment whose local characteristics are such that the system and the environment are able to exchange "information" in some way and thereby influence or modify each other. Put another way, one can imagine the various environments of concern to be characterized each by some parameter set (like an Earth Standard Atmosphere model), and the various systems likewise. An environmental interaction is what occurs when one takes a system from shelf "A," an environment from shelf "B," places them into a sealed bag and shakes well. It is the objective of an environmental interactions team to classify, prioritize, and model interactions, to advocate and/or conduct all necessary experiments whether in space or on the laboratory, and to place into the hands of systems designers the best possible user friendly codes and/or design guideline documents possible. This will enable those designers to optimize their systems to the environments in which they must function, from the earliest design stages through to completion and use.

This type of work is already being carried out in a number of discipline areas, some of which have been ongoing for a considerable time. Some of these areas include radiation effects, having to do with particles and fields; collision effects, having to do with micrometeoroids and orbital debris; effects connected with dusty plasmas, like those found on the moon or in the vicinity of comet

nuclei; plasma and spacecraft charging effects, chemical processes, Martian aeolian processes, and temperature cycling effects. Systems which have historically been impacted by interactions with their local environments include the "big" missions systems like those associated with Apollo, Viking, and the planetary and cometary probes of the past few decades, geostationary satellites, which displayed anomalous behavior most readily accounted for by charge/discharge phenomena, the Space Shuttle, which has carried various payloads to determine environmental parameters at LEO (some of which were used in development of computer models) and the Space Station, whose size and complexity has led to a reconsideration of environmental interactions in LEO. The evolution in our knowledge of environmental interactions has been driven by the growth and variety of space infrastructure elements placed onto Earth orbit and elsewhere. Systems of increasing size and complexity, and placement of those systems into active new environmental regimes has repeatedly necessitated the development of new interactions knowledge and system design guidelines. The President's Exploration Initiative is orders of magnitude larger than anything attempted in space to this point in time. Therefore, our understanding of environmental interactions must again grow to meet the challenge of the future.

The environments of concern to the Exploration Initiative include at least the surface environments of the Moon and Mars, the martian atmosphere, and the space environments through which humans and cargo will travel to reach these destinations. Least known among these environments are the martian surface and atmosphere. Interactions to be anticipated when systems are placed on the martian surface include Paschen breakdown from moderate to high voltage surfaces, charge/discharge phenomena associated with electrostatically charged dust, modification of discharge onset characteristics depending on wind and wind-borne dust conditions, and charge/discharge phenomena during descent and ascent of man-made vehicles. Dust deposition will modify surface optical, electrical, and thermal properties, and wind borne dust will produce mechanical erosion over long periods of time. Chemical effects are also to be anticipated with active species in the martian atmosphere and soil. Additional thoughts on martian environmental effects are included in the appendix to this abstract.

Better known is the lunar environment in which dust dynamics are driven by electrical forces, and result in copious contamination of external and internal surfaces and volumes. Since the moon has no atmosphere, radiation and plasma effects are also important lunar surface considerations. Long term human occupation of the Moon and Mars necessitates development of systems in which interactions with the environment are understood in the earliest design phases, and taken into account throughout the design process. Similar arguments exist for translunar and interplanetary space through which humans

and cargo must pass en-route to lunar and Martian destinations, as well as to low Earth orbit which may be the site of semi-permanent human occupation in an Earth orbiting Space Station. The size and complexity of the Space Station have already been cited as drivers for developing new environmental interactions knowledge, and the issues which have arisen (with such design parameters as Space Station structure to solar array grounding) must serve as fair warning of the need for constantly updating our interactions models and/or developing and experimentally validating new ones, as necessity determines.

To date, environmental interactions work has been carried out in several specific areas and completed to varying degrees. But this work has not been carried out in the "Integrated Program" fashion necessary to the scope and magnitude of a Space Exploration Initiative. The respective disciplines have evolved semi-autonomously, that is, to a large extent independently of each other. Cross fertilization of ideas has occurred only as needed, as when the question of a plasma interaction arose around the issue of a solid object like a meteoroid impacting or penetrating a spacecraft bumper shield and generating a hot transient gas as a by-product. No forum yet exists in which system/plasma interactions are discussed on a large scale, with cross-disciplinary exchange of ideas, and development of integrated program elements which both insures minimal overlap of funded efforts and fills all of the programmatic "holes."

An integrated, coordinated approach is required for future work in this area, allowing programs to develop with mutual knowledge of each other and knowledge of the mission and system definition activities already under way. To that end, a working group has been established to address issues and make recommendations, defining agency-wide areas of need for predicting and evaluating interactions, establishing what information is already available, and formulating and implementing a program to develop and experimentally validate models for use by system design engineers. As a point of ingress into a potentially infinite area of study, the Environmental Interactions Working Group will begin by establishing requirements for robotic missions to Mars. The group will establish a data base of currently available information on the Martian surface environment, and understand in broad terms the expected operating parameters of systems intended for use on the martian surface. It will then define and prioritize martian surface interactions, and establish those parameter sets most critical to developing interactions models. The parameter sets will be compared against existing data, and used to define instruments, sensors, and/or experiments to be carried to the martian surface as part of the robotic precursor "package." These items will be documented in the form of a set of recommendations, and delivered to the Engineering Requirements Working Group being established at the Johnson Space Flight Center. The working group will

expand its activities to embrace the broader charter described above as appropriate. It will meet by videoconference approximately every six weeks, and more frequently on an as-needed basis.

APPENDIX: OUTLINE OF PRELIMINARY THOUGHTS ON MARS SURFACE INTERACTIONS

The following outline represents preliminary thoughts on electrical system/environment interactions on the planet Mars. These types of interactions should be of interest to system designers at every stage of system design.

I. ATMOSPHERIC INTERACTIONS

- A. Paschen electrical breakdown from high voltage surfaces: (The 7-9 Torr atmospheric pressure at the martian surface is ideal for Paschen breakdown over mm to cm distances at a few hundred volts, and cm to m at a few kilovolts)
 - 1. breakdown to other spacecraft surfaces
 - 2. breakdown to air
 - 3. breakdown to ground
 - 4. source of system power loss
 - 5. source of electromagnetic noise
- B. Sparks, arcs, and other sustained or transient discharge phenomena
 - 1. electrical power loss
 - 2. sputter erosion of surfaces
 - 3. transport and redeposition of materials (contamination)
- C. Electrical discharge phenomena during descent and ascent (unknown)
 - 1. electrical breakdown of low pressure atmosphere and local gases due to thruster firing
 - 2. differential charging of surfaces during thruster firings
 - 3. analogous to discharge events seen during terrestrial launches

II. MARTIAN IONOSPHERE/SPACECRAFT INTERACTIONS IN LMO (100-300KM)

- A. Plasma phenomena are functions of system voltage, system configuration, and local particle populations
- B. Max neutral number density = 10^9 and 10^{12} cm^{-3} for monatomic oxygen and CO_2 respectively (compare 10^9 cm^{-3} for monatomic oxygen in LEO)
- C. Max electron density = 10^4 to 10^5 cm^{-3} (compare 10^5 to 10^6 cm^{-3} in LEO)
- D. Max ion density = 10^4 to 10^5 cm^{-3} for CO_2^+ and O_2^+ respectively (compare 10^4 to 10^6 cm^{-3} for N^+ and O^+ respectively in LEO)
 - 1. PIX II showed evidence of arcing and parasitic current collection at 10^4 cm^{-3} electron number density
 - 2. PIX II operating voltages = +/- 750 volts

- E. Concerns include spacecraft surface charging, sputtering from charged surfaces, spacecraft floating potentials, oxygen degradation of materials, and spacecraft system grounding

III. DUST RELATED ELECTRICAL INTERACTIONS

- A. Surface dust
 - 1. charging due to solar ultraviolet
 - 2. charging due to induced dipole effects from exposed high voltage surfaces
 - 3. deposition on surfaces due to electrostatic attraction
 - 4. modification of surface thermal, optical, and dielectric properties
 - 5. contamination of clean volumes
- B. Wind borne dust
 - 1. charging due to frictional mechanisms
 - 2. charging due to differential settling after dust storms
 - 3. deposition of electrically charged dust on surfaces
 - 4. modification of surface thermal, optical, and dielectric properties
 - 5. contamination of clean volumes

IV. INTERACTION MODELS: WHAT HAPPENS WHEN YOU ADD A SYSTEM TO AN ENVIRONMENT AND "SHAKE WELL?" HOW DOES ONE CHARACTERIZE THE RESULTING INTERACTION AND USE THAT KNOWLEDGE TO PRODUCE THE BEST DESIGN? SOME AREAS FOR CONSIDERATION/DEVELOPMENT ARE THE FOLLOWING:

- A. Identify relevant physical mechanisms/equations
- B. Produce, and (where necessary) experimentally verify mathematical models
 - 1. identify existing interaction models where applicable
 - 2. identify and direct models currently under development in related areas
 - 3. identify areas for which model development needs to be initiated (SEI specific models, or working modules for use with existing models)
- C. Understand user needs and establish appropriate user interfaces
 - 1. system designers are the most likely users
 - 2. interaction models are a bridge between standard environment models and engineers who wish to understand how their new system will play in a given environment
- D. Establish appropriate input/output formats
- E. Identify/perform relevant laboratory/space tests and analyses
- F. Deliver user-friendly software with appropriate interfaces